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The Effects of Pattern Difficulty During Prior Form Experience Upon Laterdiscrimination Learning.

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THE EFFECTS OF PATTERN DIFFICULTY DURING PRIOR FORM EXPERIENCE UPON LATER DISCRIMINATION LEARNING

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ABSTRACT

The present study served as an investigation into the area of prior environmental non-reward contingent visual stimulation and later discrimination of these stimuli. The results reported in the literature on prior exposure to visual patterns and later discrimination of these patterns are contradictory--seven of the studies show positive (facilitating) effects; nine show no beneficial effects. Many of the previous investigations have employed the circle and triangle as the pair of rearing and discrimination patterns. As these stimuli have been reported elsewhere to be difficult to discriminate, it could be that the failure to achieve positive effects of rearing with these patterns might be due to their difficulty of discrimination during rearing.

The present investigation was undertaken to ascertain whether a pair of easier patterns exposed during rearing might not have some facilitating effect on later discrimination of these patterns. To guard against the possibility that the easy patterns might be so easily discriminated during discrimination (even by the control group receiving no rearing exposure) that any facilitating effect might not have a chance to manifest itself, a third set of patterns was employed that had been reported to be of

intermediate difficulty between the easier and more difficult patterns.

Thirty-six albino rats were reared, four per cage, from the time their eyes opened until they were fifty days of age in solid-walled cages with a pair of either the easy, intermediate, or difficult patterns suspended on every wall, and thirty-six subjects were similarly reared only without the patterns. At the end of the 50 day rearing period the patterns were removed from the walls of the experimental groups' cages, and discrimination trials were run at the rate of ten trials per day for 15 days, and 20 trials per day for 15 days. The experiment was run in three equivalent phases, one-third of the experiment being run each time.

An analysis of the results indicates that rearing with an easy pattern (horizontal and vertical striations), or an intermediate difficulty pattern (U, inverted U) has no facilitating effects on discrimination of these patterns at a later time. However, rearing with difficult patterns (circle and triangle) has a significant facilitating effect on later discrimination. Furthermore, the effect of replication, sex difference, particular pattern of a pair reinforced, or trials did not significantly influence or account for the results. The learning curves for each of the groups were essentially regular and progressive,

suggesting that there are no early facilitating effects balancing later inhibitory effects.

The finding that rearing with circles and triangles has a highly significant effect on discrimination, along with the fact that these patterns are extremely difficult to discriminate at 50 days of age for a control group, suggests that there is some early critical period during which these patterns are discriminated. Furthermore, it was found that rearing with easy patterns depresses later discrimination. These two findings suggest that the investigation of early facilitating and/or inhibitory effects merits further study.

A method was proposed whereby the effects of early exposure to stimuli could be investigated in detail, and a need was expressed for a more efficient and direct method of measuring discrimination.

INTRODUCTION

Psychologists have known for some time that the type of early experience provided an animal can effect his adult performance on a variety of tasks (Beach and Jaynes, 1954; King, 1958; Sanchez-Hidalgo, 1962). Several researchers (Bingham and Griffiths, 1952; Dawson and Hoffman, 1958; Forgays and Forgays, 1952; Forgays and Read, 1962; Forgus, 1954, 1955; and others) have demonstrated that rats reared in complex environments are superior in problem solving ability at a later time to those not provided such experience. Furthermore, investigators (Denenberg, 1958; Denenberg and Karas, 1960; Forgays and Read, 1962; Forgus, 1956; Hymovitch, 1952; Liu, 1928; Meyers, 1962; Soskin, 1960) have found this experience has the greatest effect when it occurs relatively early, especially before weaning. In spite of these findings, King reports only three studies in his 1958 review that experimentally varied early experience before 20 days.

There are few studies which have been devised to experimentally test the effect of early exposure of some particular stimuli on the later behavior to these same stimuli. Of particular relevance to higher animals is the

effect of visual experience on behavior. Since most behavior occurs without contingent reinforcement, of particular interest would be free visual experience with certain stimuli and the effects of such experience upon later behavior. King (1958) in his review of early experience variables affecting adult behavior reported no experiments on the effects of free visual experience on later discrimination learning.

There have been only ten experiments reported in the psychological literature that are directly relevant to the effects of early exposure to visual patterns and later discrimination of these patterns. These studies are based in part on Hebb's (1947) statement which predicted that animals that have had a large amount of perceptual experience in early life are prone to be better learners than those deprived of such experience.

Gibson and Walk (1956) started the investigation on early form experience on later discrimination with a study in which rats were reared from birth to 90 days of age in cages with circles and triangles exposed, and then tested on discrimination of these forms. The group exposed to these patterns discriminated the circles and triangles significantly better than a control group not exposed to these patterns. Also Gibson et al., (1958, Part I), in testing to see if rearing with one set of patterns would

facilitate the discrimination of similar patterns, reared two groups of subjects with circles and triangles from birth to 90 days, and found that these subjects were significantly better at discriminating a circle and a triangle, and an elipse and isosceles triangle, than two control groups not exposed to patterns. In a second study (1958, Part II) to investigate whether differential viewing habits during rearing would affect later discrimination, one group of subjects was reared with circles and triangles (E1), one group with no patterns (C1), and a third group (CE1) with painted rocks which provided something to view without a regular pattern. One-half of each group were then tested on discriminating a circle and triangle, or horizontal and vertical striations. The only significant finding was that the group (E1) reared with circles and triangles discriminated these forms better than the control group (C1) not exposed to these patterns.

Forgus (1956) displayed a triangle and a cross on one end of rearing cages of rats, and a square and triangle on the other end from the time the subjects were 16 to 41 days of age, and from 41 to 66 days, with a control group not exposed to patterns for each of the experimental groups. In testing the ability of the animals to discriminate only the triangle and cross, it was found that early visual experience benefited the experimental group, and that the earlier

exposure was significantly more beneficial than the later. The age at testing was not a factor in these findings because the two control groups tested at different ages did not differ in their ability to discriminate the patterns.

However, although Forgus (1958a) found that groups reared with circles and part triangles (angles only or sides only) discriminated circles and whole triangles better than a control group reared without patterns, a third experimental group reared with circles and whole triangles did not discriminate these patterns better than the control group.

In another investigation (Forgus, 1958b), four groups of subjects were reared with circles and one of four non-continuous triangles (side form, incomplete side form, incomplete angle, and incomplete total) and one-half of each group was tested on its ability to discriminate a circle and a triangle, and one-half on its ability to discriminate the patterns with which it was reared. Two groups discriminated the circle and triangle better than the patterns with which it was reared; the other two groups discriminated the form with which they were reared better than the circle and triangle.

In testing to see if a comparison of the forms is necessary during rearing to facilitate later discrimination of these stimuli, Walk et al., (1958, Part I) reared subjects

From birth to 120 days of age with either a triangle or a circle on each cage wall, and found that both groups exposed to one of the patterns discriminated a circle and a triangle significantly better than a control group not exposed to patterns during rearing. However, (Walk, et al., 1958, Part II) in testing the effects of actually feeding the subjects from 30 to 100 days in the presence of only the circle, only the triangle, or both the circle and triangle, it was found that neither reinforcement with, nor exposure to, benefited the experimental group over the control group reared without patterns in discriminating a circle and triangle.

Meier and McGee (1959) report that subjects reared with three-dimensional objects (rectangles, squares, half-circles, triangles, and rectangles from which half circles had been cut) exposed through a pane of glass were better at discriminating a cross from a triangle than subjects reared in cages that prevented visual experience with patterns, but had no advantage in discriminating these forms over control subjects reared in a normal laboratory environment.

Gibson et al., (1959) undertook a series of three new experiments to attempt to explore some variables which could have had some effect on their earlier inconsistent results. In the earlier experiments (Gibson and Walk, 1956; Gibson et al., 1958) the patterns were left in the cages of the

experimental group even after discrimination training began. In the first new experiment (Gibson et al., 1959, Part I) one group of subjects was exposed to circles and triangles from birth to ninety days at which time discrimination training began; a second group was exposed to these patterns only after discrimination training began. Neither of the experimental groups discriminated circles and triangles better than a control group which was not exposed to any patterns.

In the second new experiment (Part II), groups exposed to circles and triangles from birth to 50 days and during discrimination training, and from 50 to 90 days and during discrimination training, were not significantly better at discriminating circles and triangles than a control group not exposed to patterns. The third new experiment, (Part III), which compared a group reared in the dark from birth to 90 days, a group reared from birth to 90 days and during discrimination with circles and triangles (essentially a replication of the 1956 experimental group), and a control group reared with light but no patterns, resulted in no significant differences among the three groups in discriminating circles and triangles.

Libaw (1961) reared groups of rats from 24 to 91 days in six conditions (darkness, non-patterned light, straight line, two lines and included angle, triangle, normal visual

environment) and found no significant differences between these groups in discriminating a circle and a triangle. Also Baird and Becknell (1962) reared groups with either triangles and circles or rectangles and circles from 26 to 85 days of age. They tested one-half of each experimental group's subjects on their ability to discriminate a circle and a triangle, and one-half of each experimental group's subjects on their ability to discriminate a circle and a rectangle. No effect of early experience was found when the experimental groups were compared with a control group receiving no early exposure to patterns.

These results are at best contradictory and conflicting, with seven studies (Gibson and Walk, 1956; Gibson et al., 1958, I, II; Forgus, 1956, 1958b, one-half; Walk, et al., 1958, I; Meier and McGee, 1959 part) showing positive evidence for facilitation effects of early experience on later discrimination, and nine studies (Forgus, 1958a, 1958b, one-half; Walk et al., 1958, II; Meier and McGee, 1959 part; Gibson et al., 1959, I, II, III; Libaw, 1961; Baird and Becknell, 1962) showing no such advantages.

Since discrimination ability is basic to both preference for and differentiation between two or more patterns, it is felt that the ease with which patterns can be discriminated in rearing as well as during discrimination is a major variable in the effect of early experience upon

later learning. Thus it may be that the contradictory results that have been reported on the effects of early experience are due to the fact that the patterns displayed are very difficult to discriminate. Of the sixteen studies mentioned above, only three did not employ the circle and triangle as either the rearing stimuli, the discrimination stimuli, or during both phases. Both Munn (1950, p. 147, and Gibson et al., 1958) note the difficulty of discrimination between these two stimuli by rats.

In order to examine the possibility that the difficulty level of the patterns used in previous studies may have led to the inconsistent results, three separate pairs of patterns were employed in the present study. The circle and triangle were used as a difficult pair of stimuli. The use of these patterns was also, in effect, a partial replication of the majority of the experiments in this area. Horizontal and vertical striations were utilized as the pair of stimuli which have been reported to be very easy to discriminate (Munn, 1950, p. 146, "Almost all normal rats jumped without training to the horizontal lines). In order to anticipate a situation which might occur if the striations were so easily discriminated and learned that the effects of early exposure would have no chance to make themselves manifest, a third pair of patterns (U and inverted U) was used, these patterns have been shown to be of intermediate difficulty

between the extremely easy and extremely difficult patterns (Munn, 1950, p. 151).

Thus, there was an experimental group exposed to a pair of difficult, intermediate, and easy patterns during rearing and a control group for each experimental group receiving no patterns during rearing. Any differences in discrimination learning between the experimental groups over the control groups could only be attributed to the facilitating effects of early rearing experience with patterns. Any differences in discrimination learning among the experimental groups could be attributed either to the effects of level of difficulty of patterns during rearing, or to the level of difficulty of discriminating the patterns at training. The comparisons of the discrimination learning of the control groups would indicate the difficulty of the patterns during discrimination training. It would then be necessary only to compare each experimental group with its appropriate control group on discrimination learning to ascertain if the experimental treatment during rearing had any differential effect. It might be that there would be a facilitating effect of rearing with exposure to the easier patterns, while there would be no such facilitating effect for rearing with difficult patterns. A comparison of each of the experimental groups with its appropriate control

group would ascertain the differential effects of rearing exposure versus non-exposure for each of the three levels of difficulties of patterns.

Thus, with various comparisons of the results of the present experiment one could ascertain: the effects of patterns versus no patterns during rearing [Experimental (E) vs. Control (C)]; the difficulty of the three patterns during discrimination (C1 vs. C2 vs. C3); and the effects of exposure versus no exposure during rearing for each of the three levels of difficulty of patterns (E1 vs. C1, E2 vs. C2, E3 vs. C3).

METHOD

Subjects

The subjects (Ss) consisted of 49 male and 23 female naive albino rats (Badger Research; Sprague-Dawley Strain).

Six females with their pups were obtained for each phase. The litters were randomly split and four pups and a mother were housed in each of six rearing cages before the pups' eyes opened. Thus, all subjects were "born" visually into their environments. The Ss were weaned at 28 days of age and the mothers were removed.

Rearing

The investigation was run in three equivalent phases. During each phase four subjects were reared in a cage with circle and triangle patterns: 4 Ss with U and inverted U patterns; 4 Ss with horizontal and vertical striation patterns; and 4 Ss in each of three cages with no patterns. Thus 12 Ss were reared in each of the three experimental conditions and each of the three corresponding control conditions, giving a total of 72 Ss.

The 10" x 10" x 10" rearing cages had solid floors and walls with 1/4 inch hardware cloth ceilings. The solid walls minimized experience with visual patterns except for

those provided the experimental groups. The interiors of the cages were painted flat white.

Metal panels, 4 inches square were painted flat white. One pattern was painted in flat black on each of the panels to be exposed in the cages of the experimental groups. The panels were hung in pairs one inch apart on each of the four walls of each cage with their bottom edges 1-1/2 inches above the floor of the cage.

The control groups were exposed to only blank flat white panels during rearing. Each experimental group was exposed to one pair of patterns on each of the four walls of the cage.

Experimental group one (E1) was exposed to four 3-inch diameter circles and four triangles 3-1/2 inches on a side. Experimental group two (E2) was exposed to four U's which were 1/2 inch thick and 3 inches on a side, and four equivalent U's which were inverted. Experimental group three (E3) was exposed to four panels which had 3 horizontal striations which were 1/2 inch thick, 3 inches long and 1/2 inch apart; and equivalent striations which were rotated 90 degrees to the vertical position.

Each pattern of a pair was on the left two times and on the right two times. All Ss were treated equally, except for the 3 different pairs of patterns for the experimental groups and the lack of patterns for the control groups.

Food (Wayne's Lab Blox-Lo D) and water were always available during the rearing period which began prior to the time the S's eyes opened and terminated when they were 50 days of age. Two 100-watt light bulbs provided constant illumination for the whole rearing room.

Discrimination Training, Apparatus —

The discrimination apparatus was constructed similar to the one used by Gibson and Walk (1956), following Baker and Lawrence (1951). The apparatus was a box 24 inches long, by 10 inches wide, by 10 inches high, with a guillotine door that separated the box into two equal compartments. At the far end of each compartment there were two 4 x 4 inch square openings behind which was a panel that could be moved from side to side. The pattern of a pair that was to be positively reinforced was painted in flat black on the center of this panel, and the pattern that would not be reinforced was painted in flat black on each side of this positive pattern. In the center of each pattern there was a small (1-1/8 inch square) door hinged at the top which could be opened by a gentle push by the S's nose. Behind the door of the positive pattern, on a platform 1/2 inch below the opening of the door, wet mash was located. Thus, by sliding the panel from side to side, the positive pattern could be exposed on the right or left (and its corresponding negative

pattern on the left or right) in rapid succession. These patterns were the same size as those used in the rearing cages and appeared through the 4 inch square opening at the end of the compartment at the same height and distance apart as those in the rearing cages. Each of the patterns could be covered by a white guillotine door being lowered over it to cover the stimuli if an incorrect choice was made, or to terminate eating following a correct choice.

Pretraining

On the 49th day of the rearing period all food was removed from the S's cages, and pretraining began with the Ss 22 hours hungry at the end of the 50th day of rearing. At this time all patterns and panels were removed from the cages. Pretraining was accomplished by using blank flat white stimulus panels in the discrimination apparatus.

During pretraining each S was given ten trials to learn how to obtain food. The doors in the stimulus panels were left open during the first trial and were closed slightly on each successive trial. During each trial an S remained in a compartment until he learned to obtain food from the platform behind the door. Although it took the subjects varying amounts of time to learn to push the doors open and obtain food, each S was forced to eat five times in each compartment and an equal number of times on both

the right and left sides in a R L L R R L L R R L sequence. A 60-watt light bulb located 22 inches above the discrimination apparatus was used as a light source.

Discrimination Training

Actual training for each S began immediately after the ten pretraining trials during which it learned to eat from the blank discrimination panels. A pair of patterns was exposed in one compartment, and the animal was allowed to enter and choose. If it chose correctly, the animal was allowed to eat wet mash for 5 seconds. Then the patterns were covered by lowering two guillotine doors over the patterns and the animal began a new trial in the other compartment. If the animal chose incorrectly, both forms were immediately covered, and a new trial began in the other compartment.

Each animal received 450 trials. Ten trials were given each day for the first 15 days of discrimination training, and 20 trials each day for the following 15 days. Any animal that completed 40 successive correct trials was discontinued from further running and it was assumed that this animal correctly concluded the remainder of the 450 trials.

The experimental group (E1) that was reared with circles and triangles and its corresponding control group (C1) were taught to discriminate the circles from the triangles. The experimental group (E2) that was reared with U's and

inverted U's, and its corresponding control group (C2) were taught to discriminate U's from inverted U's. The experimental group (E3) reared with horizontal and vertical striations and its corresponding control group (C3) were taught to discriminate horizontal from vertical striations. For one-half of each group one pattern of a pair was positive, and for one-half the other pattern was positive. The positive stimulus was on both the right and left side an equal number of times during discrimination training.

The Ss were run in the same serial order each day. The order of running each phase was as follows:

Phase I	C1, E1, C2, E2, C3, E3
Phase II	E3, C3, E2, C2, E1, C1
Phase III	E2, C2, E1, C1, E3, C3

Following the daily discrimination learning sessions, Ss were returned to their cages and fed. Each cage of 4 Ss received 8 pellets per day for the first 11 days and 12 pellets per day for the remainder of the 30 day discrimination learning period. This allotment was such that the animals were run while approximately 22 hours hungry. Water was constantly available in the cages during this period.

RESULTS

The results of this study are based on the analysis of the total number of correct responses made by each subject during the 450 trials of discrimination training. These total scores for the individual subjects are arranged in Appendices A, B, and C according to rearing condition, positive (reinforced) discrimination pattern, and the sex of each subject.

Although the experimental group (E) consists of all the subjects who were reared with patterns on their cage walls, and the control group (C) consists of all the subjects who were reared without patterns, for the purposes of analysis and discussion, each group that was reared with a particular pattern will be considered as a separate experimental group, and each respective group that was reared without patterns, but was tested on a particular pair of patterns, will be considered a separate control group. Thus, there is the experimental group that was reared with and tested on circles and triangles (E1) and its corresponding control group that was reared without patterns but tested on circles and triangles (C1), the experimental group that was reared and tested on U's and inverted U's

(E2) and its corresponding control group that was reared without patterns but was tested on U's and inverted U's (C2), and the experimental group that was reared with and tested on horizontal and vertical striations (E3) and its corresponding control group that was reared without patterns but tested on horizontal and vertical striations (C3).

The means and standard deviations for each of the experimental and control groups are presented in Table 1.

Level of Pattern Difficulty

Before analysis can be made of the effects of rearing with different levels of pattern difficulty, it must be shown that the patterns utilize in the present study did, in fact, represent three distinct levels of difficulty of discrimination. Since the three control groups were not reared with patterns, but were each tested in a particular pattern during discrimination training, a difference in the control group means could only be attributed to a difference in the level of difficulty in the patterns discriminated.

A comparison of the control group means (see Table 1) indicates that the horizontal and vertical striations (Mean 367.67) are the easiest to discriminate, the U's and inverted U's (Mean 280.83) were of intermediate difficulty, and the circles and triangles (Mean 245.83) are the most

TABLE 1

MEANS AND STANDARD DEVIATIONS FOR EACH OF THE THREE EXPERIMENTAL AND CONTROL GROUPS

	Experimental		Control	
	Mean	S.D.	Mean	S.D.
Horizontal, vertical Striations	353.83	26.16	367.67	37.44
U, Inverted U	279.67	33.16	280.83	47.25
Circle, Triangle	314.33	39.48	245.83	26.12
All Groups	315.94	44.66	298.11	63.68

difficult to discriminate. The horizontal and vertical striations were significantly ($t = 4.99$, $P < .01$) easier to learn than the U's and inverted U's, and the U's and inverted U's were significantly easier ($t = 2.24$, $P < .05$) to learn than circles and triangles.

The significant differences in the scores attained by the three control groups indicate that the subjects in the experimental groups were reared with patterns of three different levels of difficulty.

Effects of Prior Rearing with Patterns

As the experimental groups were reared with patterns, and the control groups were not, any differences between an experimental group and its appropriate control group in its ability to learn a discrimination would be attributed to the effects of prior rearing.

A comparison of the mean of the experimental group which was reared with horizontal and vertical striations (Mean 353.83) and that of the control group reared without such patterns (Mean 367.67) shows that the control subjects discriminate the patterns with more accuracy, but not to a significant degree ($t = 1.05$, $P > .05$) over the experimental group.

A comparison of the mean of the experimental group which was reared with U's and inverted U's (Mean 279.67) and that of the control group reared without such patterns

(Mean 280.83) shows that the control subjects discriminate the pattern with very slightly more accuracy, but not to a significant degree ($t = .07$, $P > .05$) over the experimental group.

However, a comparison between the means of the experimental group reared with circles and triangles, (Mean 314.33) and the control group reared without such patterns (Mean 245.83) shows that the rearing with patterns had a facilitating effect on the later discrimination of these patterns, and that this effect was significant ($t = 5.01$, $P < .01$). Thus, rearing subjects with the most difficult of the sets of patterns has a facilitating effect on their later discrimination of these patterns.

Total Effects of Rearing

A comparison of the scores (see Table 1) of the total subjects ($N = 36$) reared with patterns on their walls (E) with the scores of the total subjects ($N = 36$) reared without benefit of patterns (C) shows no significant difference. Although the mean of the total experimental group (315.94) is larger than the mean of the control group (298.11), this difference is not significant ($t = 1.38$, $P > .05$). The test of significance was computed (Edwards, 1960, p. 108), taking into account that the variances were not homogeneous ($F = 2.032$). The lack of homogeneity of variance appears

to be due to the fact that both the total experimental and total control groups are each a combination of three distinct subgroups. It has already been shown that the means of the three control groups differ significantly, and that the effect of rearing has increased the scores of the lowest subgroup in the experimental group. This increase of the scores of the lowest subgroup to a point above the next highest subgroup in the experimental group (see Table 1) would lower the variance of the total experimental group appreciably.

It appears, therefore, that the pattern difficulty level must be taken into account when the results of the effects of early rearing are analyzed and reported.

Replication Effects

Of further interest was whether or not such variables as replications, sex, particular stimuli (of a pair) that is reinforced, or trials influence the results of this study in any significant way.

As this study was run in three equivalent phases, it was of interest to ascertain if there are any significant effects which could be attributed to the replication. A t-test run between the scores of the replication (see Table 2) with the largest mean (Mean 210.42) and the smallest mean (Mean 305.12) indicated that there was no significant

TABLE 2

MEANS AND STANDARD DEVIATIONS OF THE SCORES OBTAINED DURING THE THREE PHASES OF DISCRIMINATION TRAINING

	Phase I	Phase II	Phase III
Mean	305.12	305.54	310.42
Standard Deviation	60.24	58.24	49.16

difference in the replications, ($t = .33$, $P > .05$).

Thus, the results do not appear to be influenced significantly by replication factors.

Sex Differences

As sex differences were not of prime interest in this study, and all the subjects were assigned at random to the experimental and control conditions, there were not an equal number of males and females assigned to each of the patterns, to the pair of stimuli to be discriminated, to the different level of difficulty of patterns, or to the experimental and control conditions (see Table 3). Therefore, a straight-forward analysis of male-female differences is not possible. If there were more males tested on the easier horizontal and vertical striations and more females were tested on the more difficult circles and triangles (which is precisely what happened in the present study's random assignment), one could not ascertain if the higher total obtained by the males was due to a sex difference or due to the greater number of subjects exposed to easier patterns. Thus, to gain some indication of possible sex differences, a mean was obtained for each sex for each of the six individual patterns used (horizontal striations, vertical striations, U's, inverted U's, circles, and triangles). These means were then treated as scores, these

TABLE 3

NUMBER OF MALES AND FEMALES TESTED ON EACH REINFORCED PATTERN DURING DISCRIMINATION LEARNING

	Experimental		Control		Total	
Reinforced Patterns	Male	Female	Male	Female	Male	Female
Horizontal Striations	3	3	5	1	8	4
Vertical Striations	5	1	6	0	11	1
U	4	2	3	3	7	5
Inverted U	4	2	3	3	7	5
Circle	5	1	4	2	9	3
Triangle	5	1	2	4	7	5
Total	26	10	23	13	49*	23

*Inadvertantly the supplier sent all male pups for the second phase which resulted in a greater number of total males.

scores were added, a mean was found, and t-tests were run to see if any of the differences were significant (see Appendix D).

A comparison of the mean of scores for the control group (as no females in the control groups were tested on vertical striations, these means were based on the scores of the remaining five patterns) males (295) and females (272) (see Table 4) indicate that the males in general appeared to discriminate the patterns better than the females, but the differences are not significant ($t = .65$, $P > .05$). The same comparison (see Table 4) for the experimental group males (319) and females (312) once again shows the males performing better, but not to a significant degree ($t = .23$, $P > .05$).

However, while there are no significant differences in the total experimental group between males and females, there could be differences between males and females in one or more of the subgroups. An analysis of the t-tests which were run between the mean scores of the experimental groups (see Table 5) of the males and females in the horizontal and vertical striations groups (Male Mean 357.12, Female Mean 347.25, $t = .60$, $P > .05$), the U and inverted U groups (Male Mean 278.12, Female Mean 282.75, $t = .22$, $P > .05$), and the circle and triangle groups (Male Mean 317.60, Female Mean 298.00, $t = .58$, $P > .05$) indicates

TABLE 4

MEANS OF THE SCORES OF THE MALES AND FEMALES OF THE EXPERIMENTAL AND CONTROL GROUPS ADJUSTED TO ACCOUNT FOR THE DIFFERENT NUMBER OF SUBJECTS REINFORCED ON EACH PATTERN

	Male	Female	t
CONTROL GROUP	295	272	.65
EXPERIMENTAL GROUP	319	312	.23

TABLE 5

MEANS OF THE SCORES OF THE MALES AND FEMALES OF THE THREE EXPERIMENTAL SUB-GROUPS ADJUSTED TO ACCOUNT FOR THE DIFFERENT NUMBER OF SUBJECTS REINFORCED ON EACH PATTERN

	Male	Female	t
Horizontal and Vertical Striations	357.12	347.25	.60
U, inverted U	278.12	282.75	.22
Circle, Triangle	317.60	298.00	.58

that there are no significant sex differences in the three experimental groups.

It thus appears that there are no sex differences in the present study that significantly affected the results.

Differences in Pattern Reinforced During Discrimination

There is the possibility of interaction between rearing and discrimination when one of the particular rearing stimuli is reinforced. It could possibly occur that rearing with circles and triangles, for example, would have a significant effect on discrimination when the circle was positive, but not when the triangle was positive.

To investigate this possibility three two-way classifications of analysis of variance were computed with the control versus experimental groups on one axis, and one of the patterns of a pair to be discriminated versus the other pattern of the pair on the other axis, for each of the three sets of patterns (see Tables 6, 7, and 8). None of the interaction F-tests were significant, indicating that there is no differential effect of rearing interacting with the particular pattern as a positive stimulus during discrimination. The lack of significance of the F-test of the interaction between rearing conditions and the circle and triangle patterns must be qualified by the fact that there is heterogeneity of variance. However, Edwards (1960, p. 132) states that the F-test on the analysis of variance

TABLE 6

SUMMARY OF ANALYSIS OF VARIANCE OF COMPARISON BETWEEN REARING CONDITION (EXPERIMENTAL, CONTROL) AND PATTERN REINFORCED (CIRCLE, TRIANGLE) BASED ON SCORES IN APPENDIX A

Source	Sum of Squares	df	Mean Square	F
Circle vs. Triangle (A)	1666.67	1	1666.67	1.45
Control vs. Experimental (B)	28153.50	1	28153.50	24.57*
Interaction (AxB)	66.66	1	66.66	
Within Group	22913.00	20	1145.65	
TOTAL	52799.83	23		

*Significant beyond .01 level.

TABLE 7

SUMMARY OF ANALYSIS OF VARIANCE OF COMPARISON BETWEEN REARING CONDITIONS (EXPERIMENTAL, CONTROL) AND PATTERN REINFORCED (U, INVERTED U) BASED ON SCORES IN APPENDIX B

SOURCE	Sum of Squares	df	Mean Square	F
U vs. Inverted U (A)	8437.50	1	8437.50	5.98*
Experimental Vs. Control (B)	8.17	1	8.17	-
Interaction (AxB)	88.17	1	88.17	-
Within Group	28134.66	20	1406.73	
TOTAL	36668.50	23		

*Significant beyond .05 level.

TABLE 8

SUMMARY OF ANALYSIS OF VARIANCE OF COMPARISON BETWEEN REARING CONDITIONS (EXPERIMENTAL, CONTROL) AND PATTERN REINFORCED (HORIZONTAL, VERTICAL STRIATIONS) BASED ON SCORES OF APPENDIX C

SOURCE	Sum of Squares	df	Mean Square	F
Horizontal Vs. Vertical Striations	1040.17	1	1040.17	1.05
Experimental Vs. Control (B)	1148.17	1	1148.17	1.16
Interaction (AxB)	2128.16	1	2128.16	2.15
Within Group	19782.00	20	989.10	
TOTAL	24098.50	23		

remains a robust test under a variety of violations of assumptions on which it is mathematically based.

It was found, however, that the U was significantly easier ($F = 5.98$, $P < .05$) to learn as the positive stimulus in a discrimination than the inverted U for both the experimental and control groups. This finding had no practical significance for the present study, however, as there was no differential effect of rearing on either of these patterns.

The Effects of Trials

Of final interest in the present study is the question of whether or not rearing effects might occur early, intermediately, or late in the discrimination training. Also of interest were the possible facilitating effects that might occur at one point in the discrimination trials which might be obscured by inhibiting effects at other times which would tend to neutralize each other and lead to the conclusion that early rearing with patterns has had no effects at all.

Figure 1 shows the percentage of correct responses during discrimination training for each of the three experimental and three control groups in blocks of five days. (See Appendix E for percentages) Beginning on the 16th day, the trials were increased from 10 to 20 per day for each subject. During the first five days, all of the groups

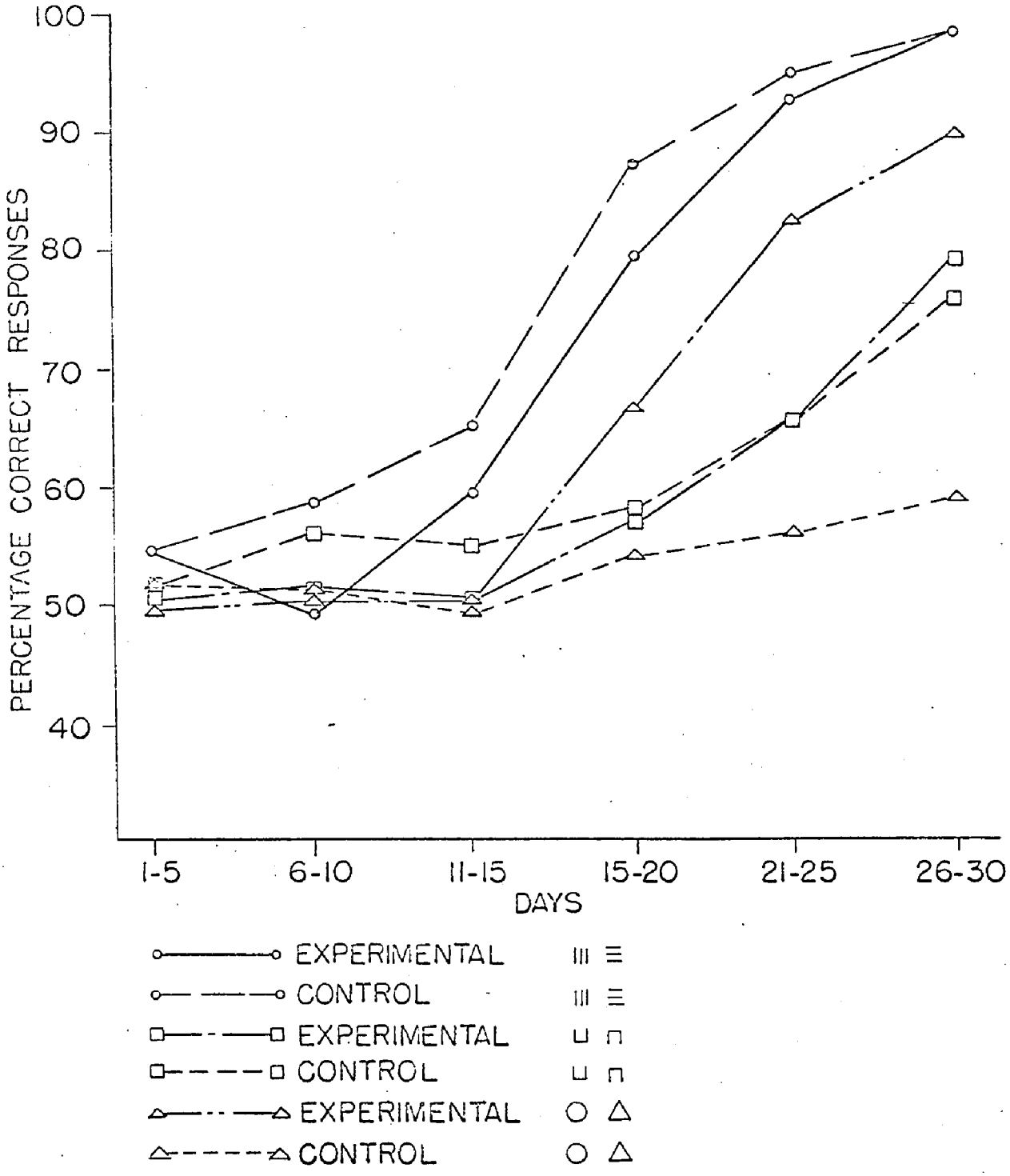

FIG. 1 THE EFFECT OF PRIOR REARING WITH THREE LEVELS OF PATTERN DIFFICULTY UPON LATER DISCRIMINATION OF THESE PATTERNS.

were performing at from 50 to 54 per cent accuracy. This performance at approximately the chance (50%) level indicates that at the beginning of discrimination learning no one particular pattern was preferred over another.

In general, the curves indicate, with minor exceptions, that discrimination learning appears to be a gradual and progressive learning process with no major peaks of facilitation or inhibition.

It would thus appear that there are no effects due to trials which would obscure the results based on total discrimination learning.

DISCUSSION

The results of the present investigation indicate that rearing subjects from the time their eyes open until fifty days of age with circles and triangles (a difficult pair of patterns to discriminate) exposed on their cage walls enables them to discriminate these patterns significantly better than subjects not exposed to these patterns during rearing. Rearing with easier patterns (U and inverted U, and horizontal and vertical striations) had no effect on later discrimination of these patterns. Furthermore, the positive effect could not be attributed to replications, sex differences, the particular pattern reinforced during discrimination, or trials.

These results indicate that level of pattern difficulty is of prime importance in evaluating the effects of early rearing with visual patterns. If one were to disregard the effects of different pattern difficulties, and compare the scores of the total group reared with patterns to those of the total control group, one would falsely conclude that rearing with patterns had no significant effects.

The results of the present study do not substantiate the hypothesis that the contradictory results reported in

the literature on the benefit of rearing with circles and triangles might have been due to the fact that these patterns were so difficult to discriminate that the effects of rearing could not manifest themselves. On the contrary, the most difficult pair of patterns (triangle and circle) were the only stimuli that showed any effect of early rearing. Rearing with an intermediate difficulty pattern (U and inverted U) or an easy pattern (horizontal and vertical striations) had no significant effects on later discrimination.

Since each of the experimental groups received identical treatment (except for the patterns displayed during rearing) the differential effects of rearing with patterns could not be attributed to such factors as genetic differences in animals, sex of subject, color of patterns, size of rearing cage, eating or drinking in the presence of the pattern, lighting, or amount of reinforcement.

The problem remains, then, to explain why rearing with easily discriminated patterns inhibited later discrimination slightly, why rearing with patterns of intermediate difficulty to discriminate had no later effects on discrimination at all, and why rearing with patterns that are discriminated with difficulty had a very significant facilitating effect on later discrimination.

One explanation would be that the two patterns that showed no significant effects of early rearing were so easily discriminated that the facilitating effects of rearing could not manifest themselves. This could theoretically be the case with the striation groups, as the control group was performing at 98% accuracy at the end of discrimination training without the benefit of rearing with patterns. However, one would have to stretch a point in the case of U and inverted U groups. The U, inverted U control group was performing at only 76 per cent accuracy at the end of 450 reinforced discrimination trials. This finding would argue against the hypothesis that this set of patterns was so easily discriminated that any beneficial effects of rearing could not manifest themselves.

The finding that rearing with easy patterns inhibits discrimination (although not significantly), rearing with difficult patterns facilitates discrimination, and rearing with intermediate patterns has no effect suggest that there might be some effect that occurs differentially with easy and difficult patterns. Adaptation to, and curiosity about the patterns are two processes that might be explored.

An adaptation theory, at first glance, looks particularly appealing as an explanation of the lower scores of the experimental striation group as compared to its control. The experimental group reared with striations could

have adapted to the patterns, and this adaptation effect could have continued into the beginning of the discrimination trials. There would be a period where an adaptation effect would interfere with the necessity to now be aware of the differences in the patterns. Reference to Figure 1 shows a depressed rate of learning for the experimental striation group (and to a lesser extent for the experimental U and inverted U group), as compared to its control, and the depression was greater in the beginning and dissipated toward the end of discrimination training.

Although the above hypothesis could account for the results found with the striation group, such an adaptation effect seems untenable to explain the total results of the study. It would seem that adaptation would occur with greater effect on patterns that are more similar than those that are dissimilar. The circles and triangles, being the most difficult to discriminate are therefore the most similar patterns. If adaptation were to have an inhibiting effect it should occur most strongly in the circle-triangle experimental group, yet this group most significantly benefited by rearing exposure.

Similarly, if the reinforcement of curiosity drives accounted for the differential effect of rearing with patterns, one would expect the greatest facilitating effects

to occur with the most dissimilar patterns. It would be expected that greater dissimilarity of patterns would lead to more curiosity, and therefore more learning. It appears, therefore, that none of these hypotheses adequately accounts for the results found in the present investigation.

The finding that is the most difficult to account for is how rearing with the circle and triangle patterns have had any differential effect on discrimination at all. These patterns are perceived as quite similar. The control group was able to distinguish these patterns at a level of only 9% above chance after 450 trials of discrimination training.

It is possible that the control group had such great difficulty in discriminating these patterns because they were not exposed to them until they were fifty days of age. Therefore, it appears that at some time previous to the beginning of discrimination training, and before the subjects were fifty days of age, the circle and triangle have, indeed, had a differential effect on the subjects. During this period the experimental subjects have been able to discriminate the circle from the triangle, and the awareness of this difference between patterns has a significant effect on their later ability to discriminate these patterns.

The question still remains that if there is some "critical period" during which the discrimination of difficult patterns results in better later discrimination, then why would not the same effect also occur for the easier patterns. It may be that pattern difficulty effects the critical period. The possibility exists that the critical period of discrimination may be of longer duration for easier than for more difficult patterns. Thus, the critical period of discrimination of the easier patterns would allow for more time for adaptation to occur to the patterns, and this adaptation would interfere with the need to later discriminate these patterns. A shorter duration of the critical period for discriminating more difficult patterns could still allow for the beneficial effects of exposure, but not the inhibiting adaptation effect.

There is also the possibility that the critical period of discriminating difficult patterns might occur later in the development of the subjects than for the easier patterns. Thus, there would be a shorter period of time for forgetting to occur between the critical period and discrimination training and the facilitating effects of the critical period of discrimination would be strong and would manifest itself in discrimination training. If the critical period of discrimination for easier patterns occurred

early in the development of the subject, there would be a period of time for either forgetting or adaptation to occur before discrimination learning began. Forgetting could possibly result in no beneficial effects of rearing with the patterns (as occurred with the U and inverted U group in the present study) and adaptation could possibly result in interference with later discrimination (as occurred with the horizontal and vertical striations group in the present study). Therefore the investigation of "critical periods" seems of significant importance to merit further study. How much experience is necessary, and when specifically must the experience occur?

The further investigation of the effects of prior rearing with patterns on later discrimination would entail looking more closely at what happens during the entire rearing period. This could be accomplished by exposing a large group of subjects to patterns during rearing, and daily testing a small sample of this group on their ability to discriminate these patterns. From the record of day-by-day discrimination performance one could ascertain: (a) whether or not the patterns could be discriminated at any phase of the subjects' development (obviously, if the patterns cannot be discriminated, they could have no subsequent effect on behavior, and thus, these patterns could be omitted from further study); (b) at what stage of their development

subjects could first discriminate the stimuli; (c) at which stage of the subjects' development the stimuli have the greatest facilitating effect on discrimination; (d) whether or not further exposure to the stimuli results in adaptation, inhibition, or any other effect; and (e) whether or not there is a stage in the development of the subjects after which a previously discriminated pair of stimuli can no longer be discriminated.

The results of studying the early rearing period would indicate whether or not a stimulus is discriminated and thus could effect later behavior. Whether or not the stimulus would have a later effect on behavior could only be ascertained by rearing subjects during the optimum periods of discrimination and measuring this effect at some subsequent time.

A methodical procedure should be considered at this time. In the type of discrimination training employed in the present study (and most others) there are at least two processes involved. The first process involved is the recognition by the subject of differences in the two stimuli to be discriminated (discrimination) and the other process is the learning of the association between a particular stimulus and reinforcement. Inspection of Figure 1 indicates that discrimination learning is a slow, gradual process. However, it may be that subjects can immediately

discriminate the differences in the patterns, but that it takes them a long time to learn the procedure of responding to the correct patterns for food.

Thompson and Solomon (1954) have described a method of measuring discrimination ability more directly. They expose subjects to two patterns for a period of time, remove the patterns, and then present the same patterns again, or one of the former patterns along with a different one. An adaptation process would suggest that there should be little differential response when two patterns are similar. However, when a novel pattern is presented there should be more response to it, and a differential response indicates that the patterns are discriminated. If this method could be automated and validated against the more traditional methods of measuring discrimination, a more direct method could be employed in investigating early phases of rearing with patterns and the effects such rearing has on later behavior.

SUMMARY AND CONCLUSIONS

The present study served as an investigation into the area of prior environmental non-reward contingent visual stimulation and later discrimination of these stimuli. The results reported in the literature on prior exposure to visual patterns and later discrimination of these patterns is contradictory--seven of the studies show positive (facilitating) effects; nine show no beneficial effects. Many of the previous investigations have employed the circle and triangle as the pair of rearing and discrimination patterns. As these stimuli have been reported elsewhere to be difficult to discriminate, it could be that the failure to achieve positive effects of rearing with these patterns might be due to their difficulty of discrimination during rearing.

The present investigation was undertaken to ascertain whether a pair of easier patterns exposed during rearing might not have some facilitating effect on later discrimination of these patterns. To guard against the possibility that the easy patterns might be so easily discriminated during discrimination (even by the control group receiving no rearing exposure) that any facilitating effect might not

have a chance to manifest itself, a third set of patterns was employed that had been reported to be of intermediate difficulty between the easier and more difficult patterns.

Thirty-six albino rats were reared, four per cage, from the time their eyes opened until they were fifty days of age in solid-walled cages with a pair of either the easy, intermediate, or difficult patterns suspended on every wall, and thirty-six subjects were similarly reared only without the patterns. At the end of the 50 day rearing period the patterns were removed from the walls of the experimental groups' cages, and discrimination trials were run at the rate of ten trials per day for 15 days, and 20 trials per day for 15 days. The experiment was run in three equivalent phases, one-third of the experiment being run each time.

An analysis of the results indicates that rearing with an easy pattern (horizontal and vertical striations), or an intermediate difficulty pattern (U, inverted U) has no facilitating effects on discrimination of these patterns at a later time. However, rearing with difficult patterns (circle and triangle) has a significant facilitating effect on later discrimination. Furthermore, the effect of replication, sex difference, particular pattern of a pair reinforced, or trials did not significantly influence or

account for the results. The learning curves for each of the groups were essentially regular and progressive, suggesting that there are no early facilitating effects balancing later inhibitory effects.

The finding that rearing with circles and triangles has a highly significant effect on discrimination, along with the fact that these patterns are extremely difficult to discriminate at 50 days of age for a control group, suggests that there is some early critical period during which these patterns are discriminated. Furthermore, it was found that rearing with easy patterns depresses later discrimination. These two findings suggest that the investigation of early facilitating and/or inhibitory effects merits further study.

A method was proposed whereby the effects of early exposure to stimuli could be investigated in detail, and a need was expressed for a more efficient and direct method of measuring discrimination.

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APPENDICES

APPENDIX A

Total Scores Made During Discrimination Training on Circles and Triangles by Subjects Reared With (Experimental Group 1) and Reared Without (Control Group 1) These Patterns

EXPERIMENTAL GROUP (E1)				CONTROL GROUP (C1)			
Circle*		Triangle*		Circle*		Triangle*	
Male	Female	Male	Female	Male	Female	Male	Female
356	327	235	269	239	233	237	249
365		318		244	242	225	233
295		334		233			258
271		351		324			233
332		319					

*Reinforced pattern of the two to be discriminated.

APPENDIX B

Total Scores Made During Discrimination Training on U and Inverted U by Subjects Reared With (Experimental Group E2) and Reared Without (Control Group C2) These Patterns

EXPERIMENTAL GROUP (E2)				CONTROL GROUP (C2)			
U*		Inverted U*		U*		Inverted U*	
Male	Female	Male	Female	Male	Female	Male	Female
311	307	297	263	313	251	208	253
275	325	246	236	298	294	376	271
257		236		336	294	233	243
327		276					

*Reinforced pattern of the two to be discriminated.

APPENDIX C

Total Scores Made During Discrimination Training On Horizontal and Vertical Striations by Subjects Reared With (Experimental Group 3) and Reared Without (Control Group 3) These Patterns

EXPERIMENTAL GROUP (E3)				CONTROL GROUP (C3)			
Vertical Striations*		Horizontal Striations*		Vertical Striations*		Horizontal Striations*	
Male	Female	Male	Female	Male	Female	Male	Female
343	375	372	379	370		379	343
361		348	339	384		402	
364		372	296	371		391	
318				385		387	
379				330		400	
				270			

*Reinforced pattern of the two to be discriminated.

APPENDIX D

THE METHOD UTILIZED IN MAKING COMPARISONS OF SEX DIFFERENCES

To compare the total scores made by males and females it was necessary to take into account the different number of subjects reinforced with each pattern. Thus, if more males than females discriminated the easier patterns, the total scores for the males would be higher, and the mean of the scores of the males would be higher than that of the females. An example will illustrate:

	Males	Females
Positive Pattern	Scores	Scores
Easy	100 100 100 100	100
Intermediate	50	50
Difficult	10	10 10 10 10
Total Scores	460	190
Mean	76.67	31.67

The means derived from the total scores would be 76.67 for the males and 31.67 for the females. These means would falsely indicate a very strong sex difference in ability to

discriminate the patterns. In the example the sexes discriminated the patterns with equal ability.

In accounting for this bias the following procedure was followed. A mean was found for all the scores for each positive pattern, and these means were treated as scores. These means were then added and divided by the number of means to obtain a grand mean for each of the sexes. In the above example the results would now become:

	Males	Females
Positive Pattern	Scores (Means)	Scores (Means)
Easy	100	100
Intermediate	50	50
Difficult	10	10
Total Scores	160	160
Grand Mean	53.34	53.34

The means for the males and females are now equal (53.34), which more accurately reflects the actual ability of the two groups in discriminating the patterns than did the means derived by the previous method.

All of the means described in the results concerning sex differences were obtained following this latter procedure.

APPENDIX E

Percentage correct responses to positive (reinforced) pattern during discrimination for each of the three experimental and control groups in blocks of five days.

GROUP	DAYS					
	1-5	6-10	11-15	16-20	21-25	26-30
Horizontal and vertical striations						
Experimental	54%	49%	59%	79%	93%	98%
Control	54%	58%	65%	87%	95%	98%
U and inverted U						
Experimental	51%	52%	51%	57%	66%	79%
Control	52%	56%	55%	58%	66%	76%
Circles and Triangles						
Experimental	50%	51%	51%	67%	82%	90%
Control	52%	52%	49%	54%	56%	59%

VITA

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EXAMINATION AND THESIS REPORT

Candidate: Robert McNeill Oswalt

Major Field: Psychology

Title of Thesis: THE EFFECTS OF PATTERN DIFFICULTY DURING PRIOR FORM EXPERIENCE UPON LATER DISCRIMINATION LEARNING

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

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